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ABSTRACT

This is one of a series of 14 instructional components of a semester-long, environmental earth science course developed for undergraduate students. The course includes lectures, discussion sessions, and individualized learning carrel lessons. Presented are the study guide and script for a learning carrel lesson on geologic time. The slides, audio-cassette tape, and other materials necessary to this lesson are not included. (BT)

SCIENCE EDUCATION CENTER

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GY-9335 (E2)

STUDY GUIDE AND SCRIPT

SECTION III: PROCESSES THROUGH TIME

LESSON 6.7: GEOLOGIC TIME

ENVIRONMENTAL STUDIES

A Cooperative Project of The Department of Geological Sciences and the Science Education Center

The University of Texas at Austin

ENVIRONMENTAL EARTH SCIENCE

"Environmental Earth Science" is a new course developed at The University of Texas at Austin by the Department of Geological Sciences and the Science Education Center. It is offered at The University of Texas at Austin as Geology 361K and has been tried out during the spring semesters of 1972, 1973, 1974, and 1975. Revisions have been made as necessary after each tryout. The project within which the course has been developed has been supported by the National Science Foundation.

The course includes lectures, discussion sessions, and individualized Learning Carrel Lessons. Extensive use has been made of multi-media technology in the presentation of the course. Learning Carrels for individualized instruction have been especially designed for this program. The lectures introduce specific topics, suggest problems or questions, and provide background information. The discussion sessions provide the student an opportunity to ask questions and clarify ideas. The discussion sessions also provide input and feedback to the instructor.

The Learning Carrel Lessons have been written by faculty and graduate students in the geological sciences and in science education. Writers and resource contributors include Dr. Robert Boyer, Dr. Rolland Bartholomew, Dr. Keith Young, Dr. Samuel Ellison, Dr. James Underwood, Dr. David Butts, Dr. Addison E. Lee, David Keller, Melanie Lewis, Wayne Schade, Ann Lee, and William McLoda. Technicians involved in production of scripts, sound, and photography were Stan Prescott, Lee West, Charles Geffen, and William McLoda. Artists were Jesus Rivas, Alice Canestaro, Aly Knox, and Javier Flores.

Each Learning Carrel Lesson consists of a set of 2 x 2 slides, an audio cassette tape, a study guide, a script, and other materials necessary to the lesson. The study guide and script are in this booklet. Students may set their own time schedule within an announced period when slides and tapes are made available.

The student should note the list of Learning Carrel Lesson topics to place in proper content the lesson in this booklet, and then read carefully the introduction, rationale, prerequisites, and lesson objectives in the study guide. The student should follow the instructions in the study guide for the entire lesson. In some instances, these instructions are also repeated on the audio cassette tape. The slides and tapes have been synchronized to automatically advance the slides appropriate to the audiotape. However, there is a tone signal given before the change of each slide so that the lesson can be used outside of the carrel if automatic facilities are not available. When the student is ready to start the lesson, the "on" switch should be pushed. If the slides and tape are operated manually, both will need to be turned "on." The first slide is always a title slide or a blank solid colored slide. If

the slides and tape are manually operated, this title or blank slide should be on view before the tape is started. For automatic operation, the slides and tapes will be set up by the Instructor or Proctor before the lesson and between each use. It is most important to start each lesson according to these instructions in order to provide synchronization of the slides and tape. Remember that slides placed in the tray to be used with a rear view screen are reversed from those to be used with a front view screen.

The student will be instructed by the study guide and/or the tape to stop at various places to carry out certain activities. Usually the audio-tape will say, "Please stop the tape now and restart only when you have finished this exercise." Therefore, the student should wait a few seconds to finish hearing the instruction after the word "Stop." However, one should not wait long enough for the tone signal or automatic change to the next slide. This signal should be heard after you restart the tape. If the lesson is moving too rapidly, the student may stop the tape and slides at any time to consult the study guide or script, but it is NOT POSSIBLE to back up and re-examine a given slide without completing the entire cycle of the lesson.

It is particularly important for the student to carry out the instructions for activities given in the study guide. In order that a record may be maintained of these activities, each student should pick up a copy of the STUDENT RESPONSE SHEET which include questions to be answered and the other activities requiring responses. These should be completed and turned in to the instructor as required for grading, feedback for the instructor, and to provide a basis for student interaction in the discussion group.

Each Learning Carrel Lesson is independent within the context of the course. Some of them provide direct information on a given topic, but in an individualized mode requiring some activities and thought on the part of the student. Others place the student in a role-playing situation where some position must be taken on provocative questions or issues. Others deal primarily with applications of environmental information. In all the lessons, the student is expected to receive basic information that is coordinated with the lectures, the small group discussions, and the readings.

ENVIRONMENTAL EARTH SCIENCE

LEARNING CARREL LESSONS

STUDY GUIDE FOR LEARNING CARREL LESSON

6.7

GEOLOGIC TIME

ENVIRONMENTAL STUDIES

A Cooperative Project of the Department of Geological Sciences and the Science Education Center

THE UNIVERSITY OF TEXAS AT AUSTIN

TO THE STUDENT:

This booklet contains two sections: (1) the Student Study Guide for this lesson, and (2) the Script or printed copy of the discussion recorded on the audio cassette tape.

You are expected to begin with the printed instructions in the Study Guide and follow them continuously as you study the lesson. In many instances the same or similar instructions may also be heard on the audio cassette tape. Refer to the script only if you need to refresh your memory as to something that was said. The script is provided because you cannot back up the tape if you need to review something already said on the tape.

Specific instructions will be given in the Study Guide as to when to start and stop the tape. Do not restart the tape until instructed to do so in the Study Guide.

Questions requiring written answers should be completed on the STUDENT RESPONSE SHEETS provided by the Instructor.

INSTRUCTIONS:

1. Start the audio cassette tape and slides. Listen to the tape and view the title slide, "Geologic Time." (For manually operated slide carousels, be sure the first slide on the screen is the title slide. Otherwise the slides and tape will not be synchronized.) Listen to the tape and view the slides until told to stop. Then STOP THE TAPE AND SLIDES.

2. Read the Introduction, Rationale and Objectives for this lesson that follows. If you have questions, check with the Instructor or Proctor.

INTRODUCTION:

What is time? All of us know that time is kept by clocks. What is it that clocks keep? Do all clocks keep the same time? Was time in the past the same as it is now? These are only a few of the many thought provoking questions one can ask about time.

What is geologic time? Geologic time is concerned with the age of the earth and the dating of natural processes that have shaped the surface of this planet. How do geologists measure geologic time? What kind of "clock" do geologists use to date geologic events?

The materials to be obtained from the Proctor include a stopwatch and materials for the investigation. If you do not know how to operate the stopwatch, ask the Proctor for instructions.

During this Environmental Studies program on Geologic Time you will participate in certain activities. Questions will be asked that require a written answer and you will be directed where to provide your answers. Other questions serve to generate thought and do not require written responses. At the end of this Study Guide are the answers to the questions requiring written responses. In this lesson you will also be directed to work problems stated in the Study Guide and to participate in an investigation.

RATIONALE:

Time is a dimension especially unique in the understanding of earth science. It is also intimately related to man -- his development, his interplay with his environment here on earth, his utility of resources, and ultimately his future. Experience has shown that students usually have a relatively narrow concept of what is meant by time. Within different academic disciplines, many concepts of time are encountered. In the earth sciences, a familiarity with long intervals of time which underline the work of all the sciences is essential. The major focus for the materials developed in this area will be to provide you with experiences that enlarge your concept of time and the role time plays in understanding your environment.

OBJECTIVES OF THIS LESSON:

At the completion of all the tasks associated with this program on geologic time you should be able to:

1. identify questions about geologic time that are philosophical

2. order a series of geologic events according to relative age

3. name the limitations of one method used to determine the age of geologic events

4. describe an earth process that makes an almost perfect geologic clock

5. construct a geologic time line

6. identify the assumptions on which relative geologic times are based

7. compare and/or contrast relative geologic time with radiometric time

INSTRUCTIONS:

3. Restart the audio cassette tape. Listen to the tape and view the slides until you are told to stop the tape and answer Question 1. Then STOP THE TAPE AND SLIDES. Answer the question that follows on your STUDENT RESPONSE SHEET.

Question 1

Place the letter of the correct order of the pictures shown on the slide in the spaces provided on your STUDENT RESPONSE SHEET.

INSTRUCTIONS:

4. Restart the audio cassette tape. Listen to the tape and view the slides until you are told to stop the tape and answer Question 2. Then STOP THE TAPE AND SLIDES. Answer the question below on your STUDENT RESPONSE SHEET.

Question 2

Place the letter of the correct order of the pictures shown on the slide in the spaces provided on your STUDENT RESPONSE SHEET.

INSTRUCTIONS:

5. Restart the audio cassette tape. Listen to the tape and view the slides until reference is made to Question 3 in the Study Guide and you are told to stop the tape and calculate some problems using the model given in the Study Guide. Then STOP THE TAPE AND SLIDES. Answer Question 3 through Question 7 on your STUDENT RESPONSE SHEET.

Question 3

How many lifetimes ago did Columbus discover America?

The average lifetime is 70 years.
Columbus discovered America in 1492.

$$\text{Lifetime} = \frac{\text{years ago Columbus discovered America;}}{\text{average lifetime}}$$

$$= \frac{1973 - 1492;}{70 \text{ years}} \quad = \frac{480 \text{ years}}{70 \text{ years}}$$

Columbus discovered America __(?)__ lifetimes ago.

Question 4

How many lifetimes have occurred since the death of Christ?

Question 5

How many lifetimes since the last advance of the glaciers 7,000 years ago?

Question 6

Since the beginning of man's recorded history 15,000 years ago, how many lifetimes have occurred?

Question 7

The Ice Age began 1,000,000 years ago. How many lifetimes have gone by since that time?

INSTRUCTIONS:

6. Restart the audio cassette tape. Listen to the tape and view the slides until you are told to stop the tape and answer Question 8 in the Study Guide. Then STOP THE TAPE AND SLIDES. Answer Question 8 on your STUDENT RESPONSE SHEET.

Question 8

How many years ago would the oceans have been sodium free? (Remember it is estimated that the oceans contain 15.5×10^{15} tons of sodium and that 16×10^{7} tons are deposited each year.)

INSTRUCTIONS:

7. Restart the audio cassette tape. Listen to the tape and view the slides until you are told to stop the tape and answer Question 9. Then STOP THE TAPE AND SLIDES. Answer Question 9 on your STUDENT RESPONSE SHEET.

Question 9

How many years would it take for all the sedimentary rocks to be deposited?

INSTRUCTIONS:

8. Restart the audio cassette tape. Listen to the tape and view the slides until you are told to stop the tape and do an investigation called Geologic Clocks. Then STOP THE TAPE AND SLIDES. Follow the procedures in the investigation. However, record the data you obtain and make the graphs on your STUDENT RESPONSE SHEET.

AN INVESTIGATION: GEOLOGIC CLOCKS

Introduction

Physicists have developed a model of the nucleus of an atom that portrays a nucleus as a dynamic bundle of shifting energy patterns. The positively charged protons of the nucleus repel each other, and the neutrons, which are chargeless, add mass to the nucleus. The forces that bind the nucleus together are not clearly understood. The equilibrium or balance between repulsion of the protons and the binding forces in the nucleus is often disturbed, resulting in the emission of a charged particle from the nucleus. The process is called radioactive decay.

Some of the minerals found in the earth's crust contain radioactive elements. These elements decay to more stable elements at a known rate and can be used to date events in the earth's past. The time interval during which half of a given amount of any of these radioactive materials disintegrates is known as its half-life. The reason that all of the nuclei do not decay at one time is that the behavior of nuclei follows probability, as illustrated by the model of radioactive decay in this investigation. The dynamic behavior of a nucleus is such that it is not able to remain stable indefinitely. It is impossible to tell how long a particular single nucleus resists radioactive decay. Since a sample contains millions of atoms of a radioactive isotope, the average rate of decay can be determined. Once this average rate is established by measurements, calculations can be made to determine how long it would take for 50 percent of the atoms in a given sample to decay. Again, this time is called the half-life of the isotope. Different radioactive isotopes have different half-lives.

To illustrate the role of probability in radioactive decay, you will use a model of the process.

Procedure

Mark one side of the box with an "X," and then place 100 radioactive decay markers in the box and shake it vigorously. Remove the markers that point to the marked side of the box and assume that these markers have "decayed." (Be consistent in your method of removal.) Using the data table on page 7 of this Study Guide, record the number of "decayed" markers and the number of "undecayed" markers remaining in the box. DO NOT return markers to the box. Label this "turn-1."

For "turn-2" repeat the shaking with the "undecayed" markers that were left in the box. Repeat with as many more turns as needed until the box is empty.

Follow this procedure again with two sides of the box marked (data table, page 8). Plot the number of "decayed" and "undecayed" markers against the turn number for each shake. Assume that each turn represents 1,000 years, and after constructing a graph (page 9) for each procedure, answer the following questions:

A. What was the half-life of each of your models?

B. How did you change the half-life of the models?

C. How many years would have elapsed when one-quarter of the markers remain in the box with one side marked?

D. When one side is marked, how many markers would be removed after 3,000 years?

E. When two sides are marked, how many years would have elapsed if there were 12.5 markers remaining and 87.5 markers removed?

F. What differences would it make in your results if someone added or subtracted some of the markers from the box during your investigation?

You may see the Proctor for answers to the above questions. Return to the Geologic Time program when finished with this investigation.

AN INVESTIGATION: GEOLOGIC CLOCKS

DATA TABLE: ONE SIDE MARKED

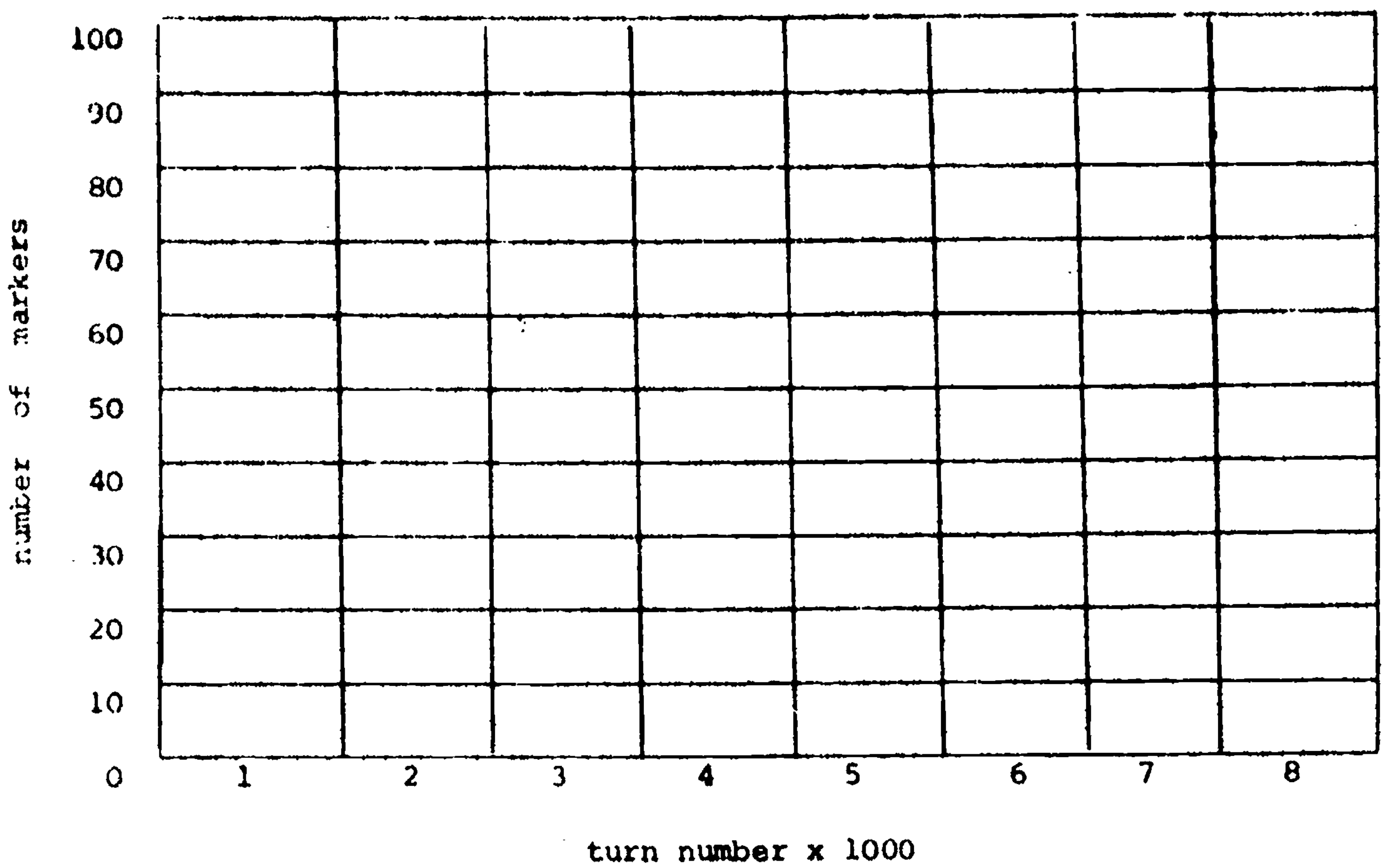
Turn-number	"decayed"	"undecayed"

AN INVESTIGATION: GEOLOGIC CLOCKS

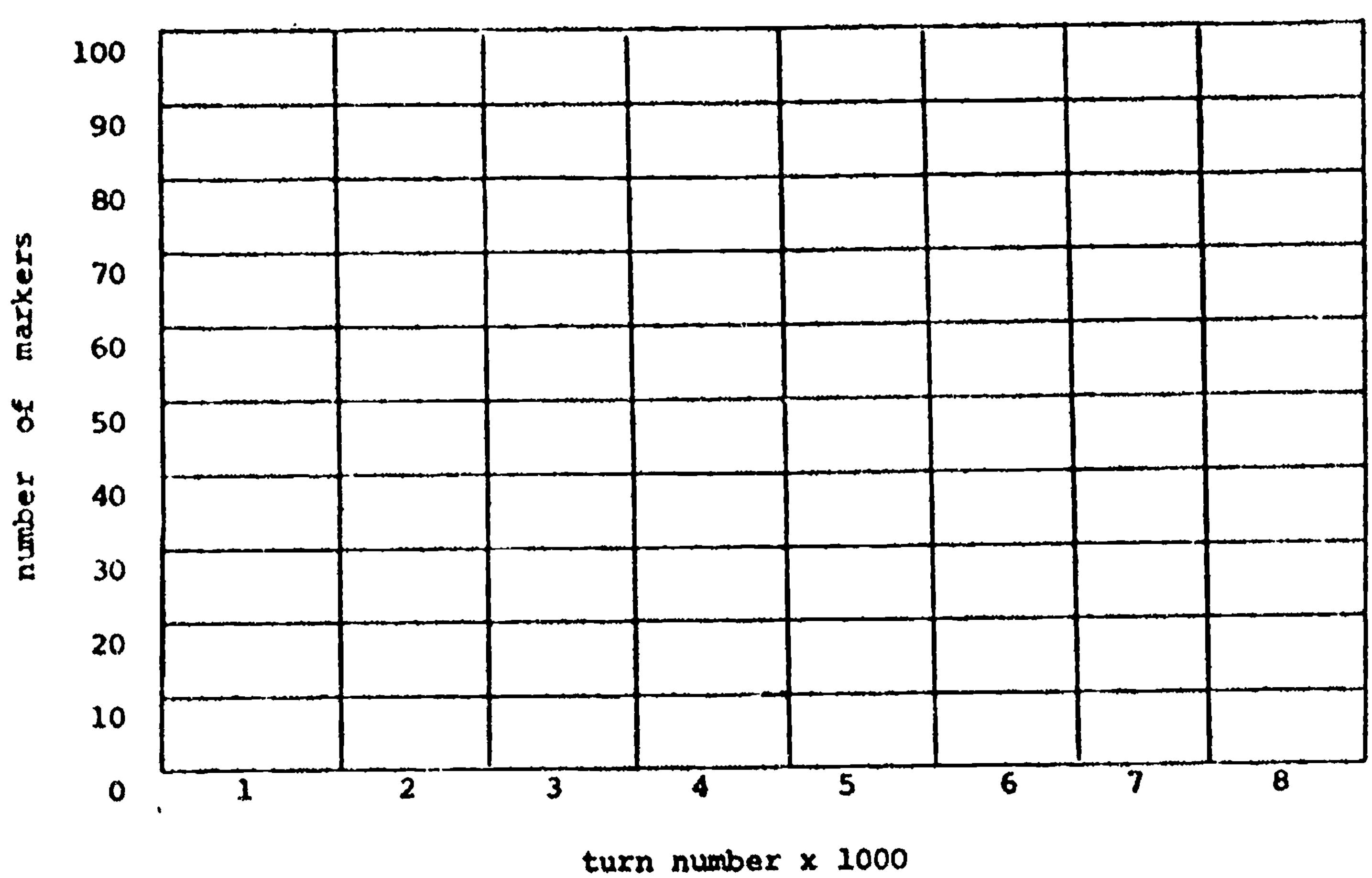
DATA TABLE: TWO SIDES MARKED

Turn-number	"decayed"	"undecayed"

RADIOACTIVE DECAY MODEL: ONE SIDE MARKED



RADIOACTIVE DECAY MODEL: TWO SIDES MARKED



INSTRUCTIONS:

9. Restart the audio cassette tape. Listen to the tape and view the slides until told to stop the tape. Then STOP THE TAPE AND SLIDES and answer Question 10 on your STUDENT RESPONSE SHEET.

Question 10

How many years have elapsed when one-quarter of the Uranium-238 remains?

INSTRUCTIONS:

10. Restart the audio cassette tape. Listen to the tape and view the slides until told to stop the tape. Then STOP THE TAPE AND SLIDES and answer Question 11 on your STUDENT RESPONSE SHEET.

Question 11

Does the amount of lead in the rock increase or decrease as the U238 decays?

INSTRUCTIONS:

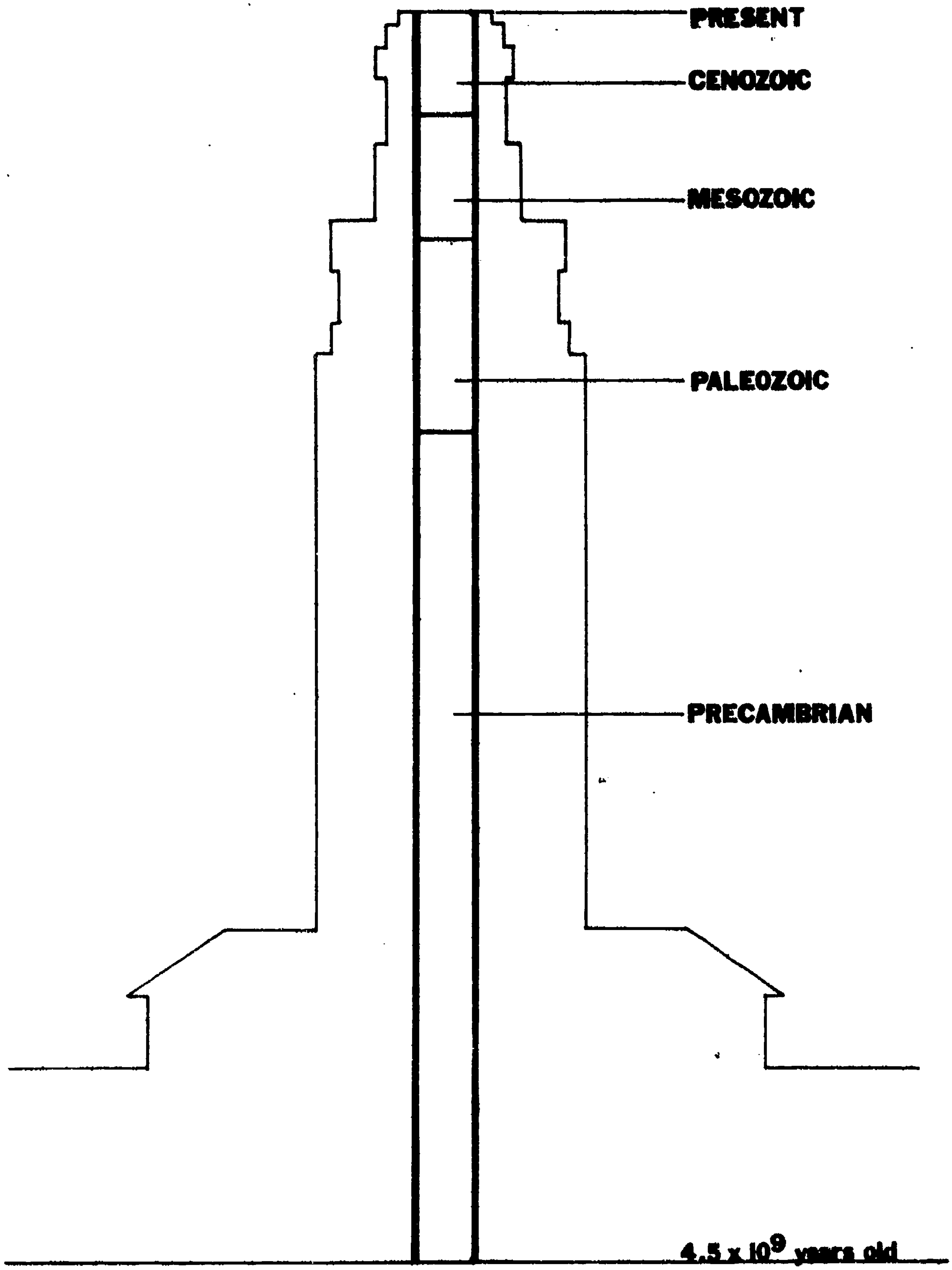
11. Restart the audio cassette tape. Listen to the tape and view the slides until you are told to stop the tape. Then STOP THE TAPE AND SLIDES and answer Question 12 on your STUDENT RESPONSE SHEET.

Question 12

How old is a rock that contains 1/8 uranium and 7/8 lead?

INSTRUCTIONS:

12. Restart the audio cassette tape. Listen to the tape and view the slides using The University of Texas at Austin tower as a time line. STOP THE TAPE when reference is made to page 11 in your Study Guide but continue to view the slide. An outline of the tower with the major geologic time intervals is shown on the following page. Compare the slide and the diagram. On the next page a geologic time chart is presented. Reference will be made to it later in the program.


PRESENT
CENOZOIC
MESOZOIC
PALEOZOIC
PRECAMBRIAN
4.5 x 10⁹ years old

GEOLOGIC TIME

Relative Duration of Major Geologic Intervals	Era	Period	Epoch	Duration in Millions of Years (Approx)	Millions of Years Ago (Approx)
CENOZOIC			Holocene	Approx. last 5,000 years	
		Quaternary	Pleistocene	2.5	2.5
			Pliocene	4.5	7
MESOZOIC			Miocene	19	26
			Oligocene	12	38
			Eocene	16	54
	Cenozoic	Tertiary	Paleocene	11	65
PALEOZOIC		Cretaceous		71	136
		Jurassic		54	190
	Mesozoic	Triassic		35	225
		Permian		55	280
		Pennsylvanian		45	325
		Mississipian		20	345
		Devonian		50	395
		Silurian		35	430
		Ordovician		70	500
	Paleozoic	Cambrian		70	570
PRECAMBRIAN	Precambrian			4,030	

INSTRUCTIONS:

13. <u>**Restart the audio cassette tape.**</u> **Listen to the tape and** view the slides until reference is made to a review of the geologic laws presented. STOP THE TAPE at this time and review the following geologic laws:

LAW OF SUPERPOSITION: In a sequence of undisturbed rock layers, the oldest rock is on the bottom of the sequence.

LAW OF ORIGINAL HORIZONTALITY: Water-laid sediments are deposited in layers that are nearly horizontal and nearly parallel to the surface on which they are accumulating.

LAW OF CROSS-CUTTING RELATIONSHIPS: The geologic feature which cuts across another is younger.

INSTRUCTIONS:

14. <u>Restart the audio cassette tape</u>. Listen to the tape and view the slides until the end of the lesson, then STOP THE TAPE AND SLIDES.

ANSWERS TO QUESTIONS IN STUDY GUIDE

QUESTION 1 Answers

Z R C T F N (If your answers are not the same, please ask about this question in the discussion session.)

QUESTION 2 Answers

W X R C (If your answers are not the same, please ask about this question in the discussion session.)

QUESTION 3 Answers

6.8+ lifetimes

QUESTION 4 Answers

28+ lifetimes

QUESTION 5 Answers

100 lifetimes

QUESTION 6 Answers

214+ lifetimes

QUESTION 7 Answers

14,000 lifetimes

QUESTION 8 Answers

97×10^6 or 97 million years

QUESTION 9 Answers

45×10^7 or 450 million years

QUESTION 10 Answers

9.0×10^8 years

QUESTION 11 Answers

increase

QUESTION 12 Answers

13.5×10^8 years

GLOSSARY

<u>deposition</u>: the laying down of potential rock-forming material; sedimentation.

<u>geology</u>: the science which treats the earth, the rocks of which it is composed, and the changes which it has undergone or is undergoing.

<u>isotopes</u>: atoms having the same atomic number but different atomic weights.

<u>natural processes</u>: processes following the many laws of nature which have occurred since the beginning of time.

<u>radiometric time</u>: time as determined by radioactive decay.

<u>relative time</u>: time as determined by relating the occurrence of an event to other events which occur either before, during, or afterwards; not concerned with placing radiometric ages to the event.

<u>time-units</u>: stratigraphic units of rocks representing some definite interval of geologic time.

BIBLIOGRAPHY

Deevey, Edward S., Jr. "Radiocarbon Dating," <u>Scientific American</u>, Volume 186, No. 2, February, 1952, pp. 24-28.

Eicher, Don L. <u>Geologic Time</u>. Prentice-Hall Inc., Englewood Cliffs, New Jersey, 1968.

U. S. Atomic Energy Commission, Division of Technical Information. <u>Nuclear Clocks</u>. 1968 (revised).

SCRIPT FOR LEARNING CARREL LESSON

6.7

GEOLOGIC TIME

ENVIRONMENTAL STUDIES

A Cooperative Project of the Department of Geological Sciences and the Science Education Center

THE UNIVERSITY OF TEXAS AT AUSTIN

1

Title Slide:
"Geologic Time"
L.C.L. 6.7

Welcome to Environmental Studies program number 7 about Geologic Time. Before we continue, please open your Study Guide to page 1 and read the material there if you have not already done so. Stop the tape and restart when ready. (Pause)

2

Wall of clocks

(Music)

All of us know that time is kept by clocks, but ...

3

(Clocks)

What is it that clocks keep?

4

Calendar,
"my birthday"
circled

Look at the calendar. A friend says you are one year older. Time marches on.

5 But what's marching on? (marching soldiers)	Does time always march in the same direction? (Pause) Does time always march at the same pace? (Pause) Does time have a beginning and an ending? (Pause) Was time in the past the same as it is now?
6 What is time?	(Clock ticking, then chimes)
7 U.T. tower	Could you answer the last question? We call this kind of question an intellectual tickler because many people find the idea of time stimulating. (Music) Anyone who knows something about time likes to te..l others what he knows.
8 U.T. tower at night	It is difficult to explain why this is so, but watch yourself in conversation with others after you finish this program.

9

U.T. tower with STOP sign superimposed on it

Could we tell earlier from later events if all the clocks in the world were stopped?

To see how this might be done ...

10

Uncracked Egg | Cracked Egg

Which event was photographed first? (Pause) How do you know? (Pause)

11

Order (Grasslands) / Disorder (Eroded hills)

Apparently, order versus disorder is one key to the direction of time. The direction of time appears to be marked by increasing disorder. There are exceptions to increasing disorder marking the direction of time.

12

Girl shuffling cards

Can you imagine the flow of time being like an endless shuffling of a deck of cards? (Sound of shuffling cards)

13

Four bridge hands

Here's a typical bridge hand dealt after long shuffling. (Pause) However, every now and then ...

14

All spades bridge hand

a bridge player is dealt a freak hand. Odds against it are great, but it still happens.

15

Spades bridge hands (LIFE)

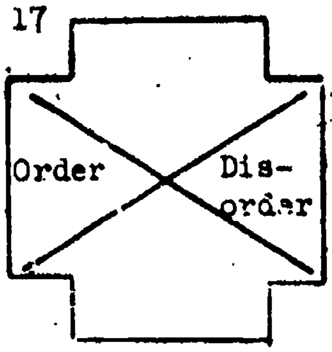
Could life have started with just such a chance accident?

16

Seven various bridge hands

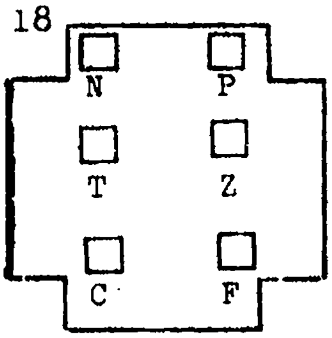
Life is self-perpetuating. Instead of disappearing on the next shuffle, it reproduces itself.

17



Life runs against the disorder of time. (Pause)

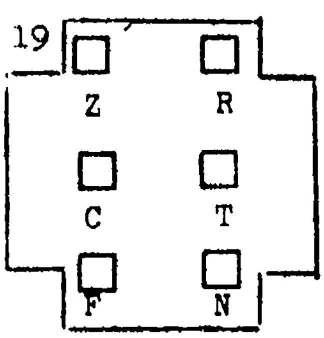
18



Six photos of several phases of a water droplet hitting a flat surface

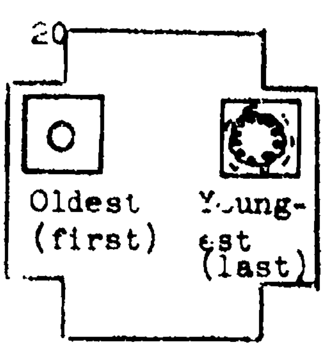
Another way to look at time is to order a series of events. What is the correct order of the events shown here? Start with the first event and end with the last event. You may stop the tape and when you are finished, please restart. Your Study Guide has answer space for Question 1 on page 3.

19



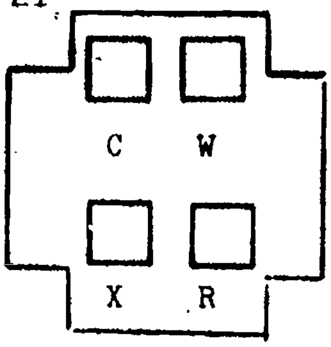
Did you order them like this? (Pause) I ordered these from oldest to youngest event. Do you see why? Did you recognize this series of events as a milk drop splash sequence? Please stop the tape if you would like to study the sequence more.

20



Most events have a beginning and an ending so we can arrange events in sequence from oldest to youngest. This is one more clue to the direction of time.

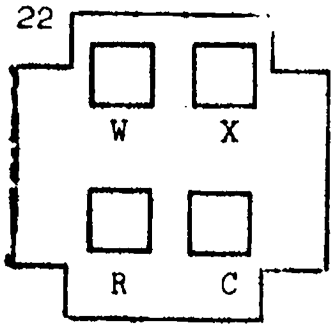
21



(Four drawings of a stream in 4 different phases of development)

How about trying again. Stop the tape and when you have answered Question 2, please restart. Remember the order please, oldest to youngest.

22



Is your order like this? (Pause) Did you order them from an oldest event to a youngest event? (Music)

23

Youngest

↑

TIME

Oldest

Time directions are also indicated by an order or sequence of events that usually have a beginning and an ending.

24

What do we mean by <u>OLD</u> ?

(Large country family)

Some people think 30 is old; others think old age starts at 50. (Pause) Consider for a moment that the average lifetime of an American is 70 years. Columbus discovered America in 1492. How many lifetimes ago was that?

25

How many life-times ago did Columbus discover America?

Will you please refer to Question 3 in the Study Guide. (Pause) Did you see how this question was solved? (Pause) Now, I would like you to calculate a few similar problems. The correct answers will appear after you restart the tape. Please stop the tape and work Questions 4 through 7.

26

Christ = 28+
Glaciers = 100
History = 214+
Ice Age=14,000+

Welcome back. They were easy, right? Here are the answers in lifetimes. (Pause) If you have any questions regarding these answers, please stop the tape and see the Proctor. (Pause)

27

Problem! Can a geologic clock be found? (rocks, hammer, & clock)

If you were going to date events that happened in the geologic past, what kind of a clock would you use? What properties would a geologic clock need to have? (Pause)

Geologists have looked for such a clock by looking at natural processes that occur at a regular rate and have existed through time.

28

Mickey Mouse clock on granite block

Can you think of any natural process that could be used as a geologic clock?

29

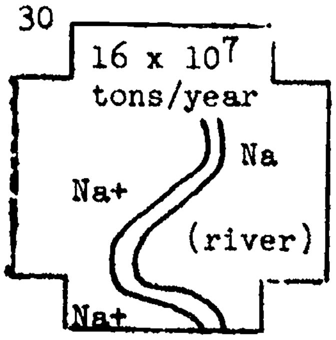
15.5×10^{15} tons

(beach surf)

One process that has occurred for a long time is the carrying of sodium from weathered rocks on land to the oceans. (Pause)

It is estimated that the oceans contain this much sodium. (Pause)

30



If rivers carry this amount of sodium to the oceans each year, how many years ago would the oceans have been sodium free?

Please stop the tape and figure the answer to Question 8 in the Study Guide.

31

97×10^6 years ago

(97 million)

Here's the answer. Clearly, it is a long time, but geologists do not consider it very accurate. Do you know why? (Pause) Several sources of error contribute to its inaccuracy as an estimate of the age of the oceans.

Has the rate of sodium transport been constant throughout this long time period? Most likely is hasn't. (Pause) It is possible the estimate of the amount of sodium is either too small or too large.

32

1. Removal by organisms
2. Formation of sedimentary rocks

Would the combination of these two sources of error make the age of the oceans too small or too large?

(Pause)

33

Too small

Did you have a similar answer? If you didn't, you may want to stop the tape and consult with the Proctor. By the way, this method was proposed in 1899, about one lifetime ago.

34

Problem! Can a geologic clock be found?

(Music) Another method used to calculate geologic time is based on the rate of deposition of sedimentary rocks.

35

450,000 ft. total

(canyon walls)

Suppose the total thickness of sedimentary rocks on earth is estimated to be this value.

36

1 ft. = 1,000 years

(canyon walls)

If the rate of deposition is estimated as shown,

37

450,000 feet total
1 ft. = 1,000 years
(canyon walls)

at this rate, how many years would it take for all the sedimentary rocks to be deposited? Stop the tape while you answer Question 9.

38

45×10^7 years (450 million)

Here is the result -- quite a long time. Now is it free of error?

Remember, I gave you estimated figures. (Pause) Suppose my estimates were wrong.

39

If the thickness is correct but the rate is too large, will the time interval be too small or too large?

Will the time interval be too small or too large if this error is made?

40

Too small

I hope this is your answer. (Pause)

41

Sources of Error:
THICKNESS
↑
Too small or too large
↓
RATE

Of course, both may be in error, so we can't really feel confident of the results we get from this kind of geologic clock.

42

A problem!
Can a geologic clock be found? (hammer, rocks, and a clock)

Imagine the dilemma facing geologists in the early 1900's. How can we date geologic events?

43

Lab technician

Nuclear Clocks

Fortunately, man has since discovered an earth process that makes an almost perfect geologic clock.

44

Corn kernels

In order for you to learn first-hand how the process works, I would like you to do an investigation called Geologic Clocks. Directions are included in your Study Guide on page 5. Please stop the tape and restart when you are finished. (Pause)

45

Welcome Back

Now that you have completed the investigation, let's review what you have learned. Please turn to page 10 in the Study Guide.

46

Graph titled "Uranium - Lead Decay Series"

Look at the graph. (Pause) How many years will have passed when one-quarter of the U^{238} remains? Stop the tape and record your answer for Question 10. Try Question 11. Does the amount of lead in the rock increase or decrease as the uranium decays? Stop the tape and record your answer. Suppose you have a rock that contains 1/8 uranium and 7/8 lead. How old is the rock? Stop the tape and answer Question 12.

47

10. 9.0×10^8 years
11. Increase
12. 13.5×10^8 years

How do your answers compare? If you have any questions, stop the tape and see the Proctor for help. You have learned that geologists now have a geologic clock which can be used to determine the radiometric age of rock specimens.

48

Hourglass, ruler, and geologic pick.

Geologists can now determine the radiometric age of long time intervals. (Pause)

Let's make a scale time line to represent geologic time. This will help you grasp the idea of the length of all geologic time. We'll use something familiar to make our geologic time line.

49

U.T. tower
4.5×10^3 inches
tall

How about this? To make things easier, let's assume the tower is 4,500 inches high.

50

Earth from a
satellite

4.5×10^9 years
old

Geologists have postulated the earth is about 4.5×10^9 years old.

51

Satel-
lite
photo of
earth

U.T.
tower

If the earth's age is 4.5 billion years old, and the tower is 4,500 inches high, what is the scale of the geologic time line? Or stated another way, how many years would one inch on the tower represent? (Pause)

52

$$\frac{4.5 \times 10^9 \text{ years}}{4.5 \times 10^3 \text{ years}} = ?$$

Here's how it's done. (Pause) Do you know the answer? (Pause) Here's a hint if you haven't determined the answer. How many years per inch?

(Pause)

53

1 inch = 1,000,000 years

I am sure you have this result too. (Pause) Our scale is one million years per inch. Using this scale, let's place some geologic events on the time line.

54

U.T. tower

The present is zero time, and is located at the top of the tower. The bottom of the tower represents 4.5×10^9 years before the present.

55

U.T. tower

The oldest dated rocks are about 3.8 billion years old. Using our scale, they would be located 315 feet from the top, or about 60 feet about the ground. The end of the Precambrian time would be 50 feet below the top of the tower.

56

U.T. tower

The Coal Age forests are about 27 feet below the top. The rise of dinosaurs about 16 feet; the beginning of the Ice Age would be about one inch from the top.

57

Top of U.T.
tower

All the events relating to man would be within one inch of the top. The Civil War would be only 11/10,000 of an inch from the top. An average lifetime of 70 years would be impossible to plot on this scale.

58

U.T. tower

Clearly, geologic time is long relative to man's lifetime and relative to a time line as high as The University of Texas tower. (Pause) On page 11 of the Study Guide, The University tower is compared to the relative duration of the major geologic time intervals.

59

Sedimentary
rocks

Igneous
rocks

Meta-
morphic
rocks

Sedimentary rock provides the most complete record of earth history and best illustrates relative time measurements.

60

K
M
D

(canyon
walls)

What evidence suggests this rock wall is composed of sedimentary rock? (Pause) Layering is one clue that suggests sedimentary rock. Can you determine which layer is the oldest? (Pause)

61

Layer D

Law of Superposition

Layer D is the oldest.

62

Law of Superposition

You have just applied the Law of Superposition to determine which layer was oldest.

Here's the law stated more precisely.

63

Now let's apply the law to this set of rock layers. (Pause) Did you choose Layer P? It's the oldest. Do you think the layers were deposited at this angle or were they tilted after being deposited? (Pause)

64

Law of Original Horizontality

Did you have to guess? Many students do because they do not know that geologists think of all sedimentary rock layers as being originally laid down horizontally.

65

Fault

What do you notice about these rock layers? (Pause) They are broken or faulted. (Pause)

66

Did the fault come before or after the rock layers were deposited? (fault)

Did the fault come before or after the rock layers were deposited? (Pause)

67

(fault)

AFTER

The reason for this answer is known as the Law of Cross-Cutting Relationships. I'll state it for you more precisely.

68

Law of Cross-Cutting Relationships

If you would like to review the geologic laws presented, please stop the tape and have the Proctor arrange the equipment.

Relative geologic time is based on these laws:

69

1. Law of Superposition 2. Law of Original Horizontality; 3. Law of Cross-Cutting Relationships

Relative geologic time is used to date different layers of sedimentary rocks and different geologic events.

70

Relative Geologic Time
↓
Time Units (years)
↑
Radiometric Geologic Time

Now we are ready to combine relative dating methods and radiometric techniques to place time units on the geologic time scale.

71

Geologic Time Chart: Eras, Periods, etc.

In your Study Guide, please turn to page 12 showing the geologic time scale. (Pause) Notice the column on the right that gives a date for each major time interval. (Pause)

(Music)

72

Original Horizontality	Superposition
Laws of Relative Geologic Time	Cross-Cutting Relationships

Before the discovery of radioactivity, geologists had been using the relative geologic time scale based on the position of sedimentary rock layers, assuming original horizontality, cross-cutting relationships, and fossil assemblages assumed to have lived at a specific geologic time.

73

Photo: watch between two rocks

After the discovery of geologic clocks, the same rock layers (provided they contained radioactive material) could be dated in radiometric time units.

74 Geologic Time Chart (same as above)

Combining the two dating methods, the geologic time scale could be calibrated in years. The result is the present geologic time scale.

---

75 Photo: assorted rocks, geologist's pick, caption: "How old are these rocks"

This explanation is a greatly simplified one, but the principle is correct. The problem isn't completely solved; the dating of rocks is one of the most active fields of geologic research.

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76 Photo: U.T. Austin, East Mall fountain, geology building

For example, The University of Texas Department of Geological Sciences has two research labs operating full-time, doing radioactive dating of rocks and geological processes.

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77 Photo: Doorway labeled "Mass Spectrometer" (room visible behind door)

This completes the program. However, if you'll walk down the hall to room 18, you'll see one of the research laboratories. Ask some of the people working there what they are doing when you have some time. (Tower chimes)

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78 The End of this Lesson

(Chimes)

LESSON 6.7: GEOLOGIC TIME

STUDENT RESPONSE SHEETS

Name ______________________________

Date ______________________________

LESSON 6.7: GEOLOGIC TIME

STUDENT RESPONSE SHEET

Question 1: Place the letter of the correct order of the pictures shown on the slide in the spaces below.

_____ _____ _____ _____ _____ _____

Question 2: Place the letter of the correct order of the pictures shown on the slide in the spaces below.

_____ _____ _____ _____ _____ _____

Question 3: How many lifetimes ago did Columbus discover America?

Columbus discovered America _____ lifetimes ago.

Question 4: How many lifetimes have occurred since the death of Christ?

Question 5: How many lifetimes since the last advance of the glaciers 7,000 years ago?

Question 6: Since the beginning of man's recorded history 15,000 years ago, how many lifetimes have occurred?

Question 7: The Ice Age began 1,000,000 years ago. How many lifetimes have gone by since that time?

Question 8: How many years ago would the oceans have been sodium free?

Question 9: How many years would it take for all the sedimentary rocks to be deposited?

Name ____________________

Date ____________________

LESSON 6.7: GEOLOGIC TIME

STUDENT RESPONSE SHEETS

AN INVESTIGATION: GEOLOGIC CLOCKS

Record data you collect in your investigation in the table below.

DATA TABLE: ONE SIDE MARKED

Turn-number	"decayed"	"undecayed"

Name ______________________

Date ______________________

LESSON 6.7: GEOLOGIC TIME

STUDENT RESPONSE SHEET

AN INVESTIGATION: GEOLOGIC CLOCKS

Record data you collect in your investigation in the table below.

DATA TABLE: TWO SIDES MARKED

Turn-number	"decayed"	"undecayed"

Name ______________________________

Date ______________________________

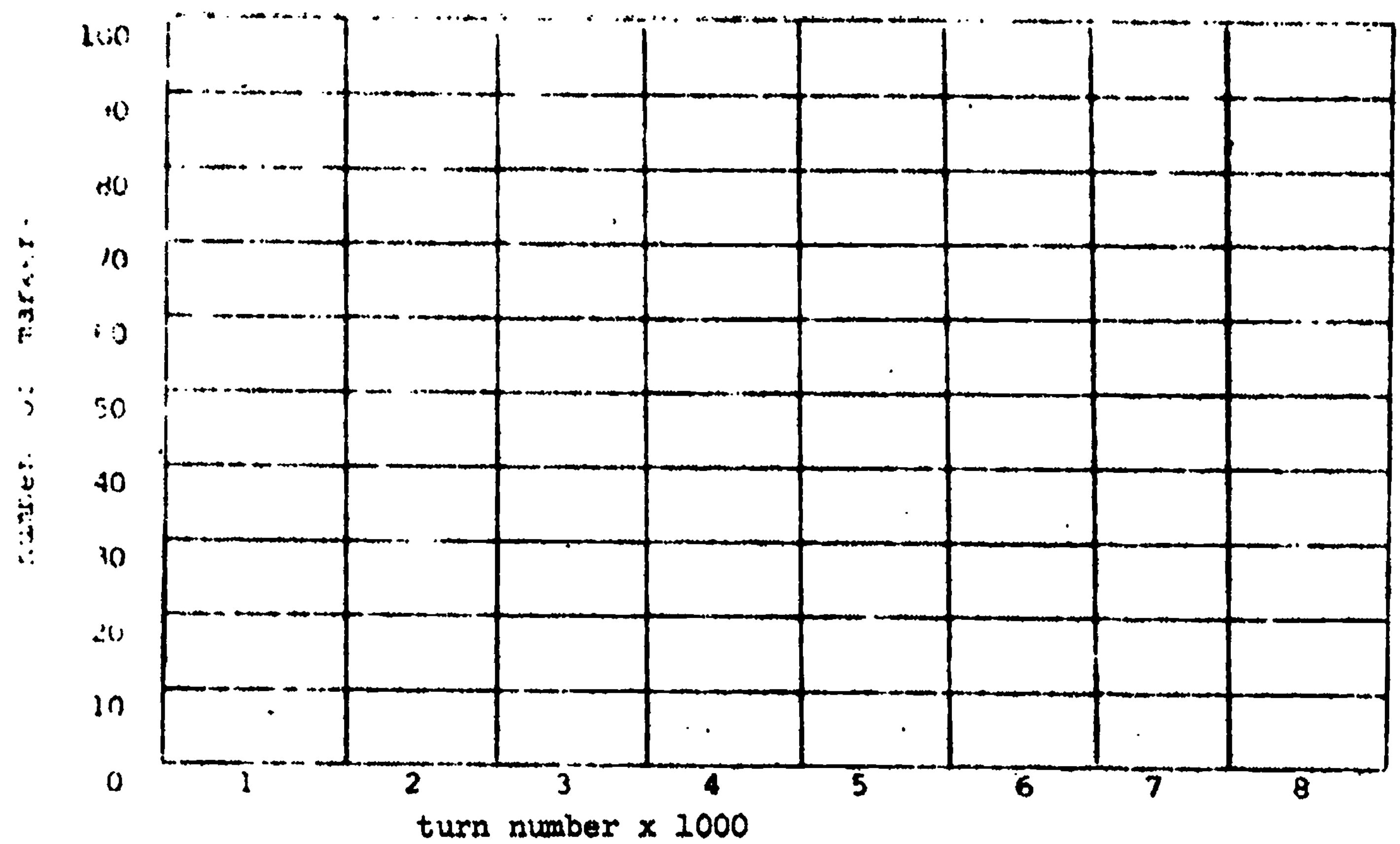
LESSON 6.7: GEOLOGIC TIME

STUDENT RESPONSE SHEET

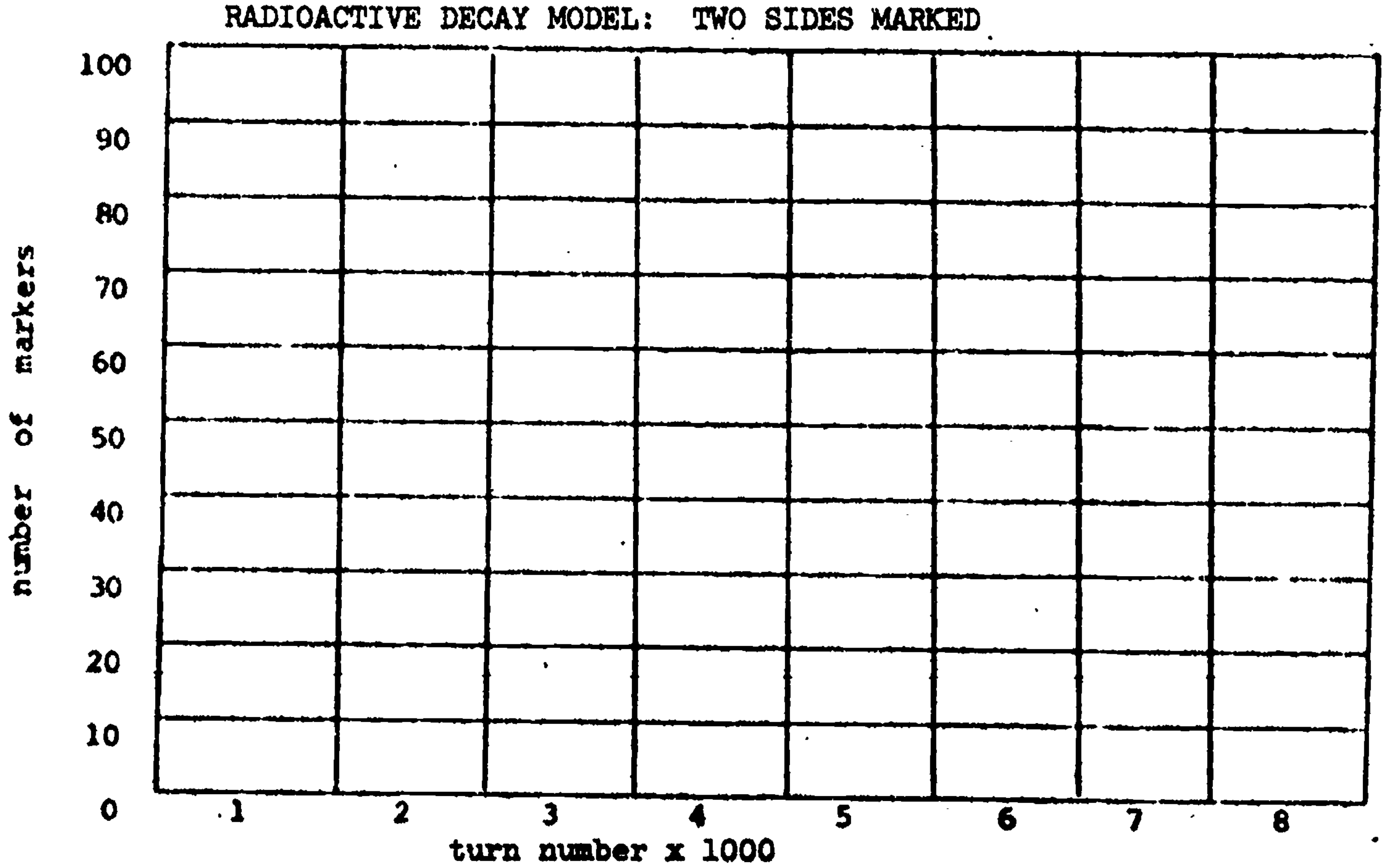
AN INVESTIGATION: GEOLOGIC CLOCKS

Record data you collect in your investigation in the tables below.

RADIOACTIVE DECAY MODEL: ONE SIDE MARKED



RADIOACTIVE DECAY MODEL: TWO SIDES MARKED



Name ______________________________

Date ______________________________

LESSON 6.7: GEOLOGIC TIME

STUDENT RESPONSE SHEET

Question 10: How many years have elapsed when one-quarter of the Uranium 238 remains?

Question 11: Does the amount of lead in the rock increase or decrease as the U238 decays?

Question 12: How old is a rock that contains 1/8 uranium and 7/8 lead?